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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

RAILROAD CAR
JOURNAL
PLAIN BEARINGS

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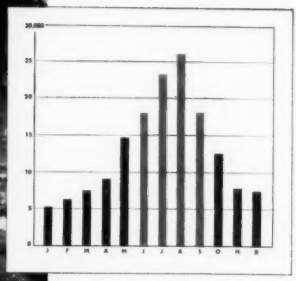
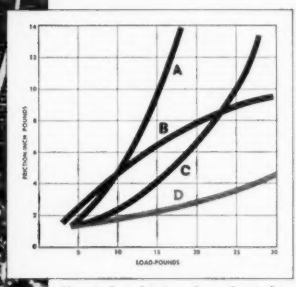


Summer heat increases hotbox setoffs more than 100%. Setoffs reported for June, July and August, 1958, represent an average of one setoff for every 119,000 car miles, compared with January average of one setoff in every 495,000 car miles.



There's less friction throughout the boundary range with Texaco Car Oil 1960 HD (curve D) than with AAR specification non-additive car oil (A) or either of two competitive premium car oils (B and C).

Hot weather need not mean hotboxes

because Texaco Car Oil 1960 HD cuts boundary lubrication friction at least 50%

Lab tests prove it. Texaco engineers developed a railroad journal testing machine that can reproduce more severe conditions than could be found on any railroad. Adjusted to simulate a very heavy loading, the machine was run with AAR specification non-additive car oil, to establish a boundary lubrication coefficient of friction of 0.1. Then, under these same conditions, Texaco Car Oil 1960 HD was found to lower the coefficient of friction to 0.005!

The chart at the top shows you how hotbox setoffs jump during the summer—more than 100% more frequent. The graph below it shows you why Texaco Car Oil 1960 HD is your best solution to this problem.

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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Railroad Car Journal Plain Bearings

Few individuals outside the railroad industry and those immediately associated with it fully appreciate the term "Car Oil". A normal reaction to this term, Car Oil, is that it must in some vague manner refer to automotive motor oil. Actually, car oil, or journal box oil as it is often called, is the lubricant used in railway freight car journal bearings[1]. It logically follows that there is little general appreciation of either the large numbers of freight cars in service today on this country's railroads, or the vast volume of oil required for the lubrication of their journal bearings, or the problems associated with their operation. Likewise, the term "hot box" is not ordinarily connected with a bearing failure, but rather something which caused an unfortunate derailment as reported in a newspaper account, or a delay in the delivery of a consigned shipment.

STANDARD JOURNAL BOX

Of the more than 1,825,000 freight cars in service today, all but a small fraction are equipped with the standard[2] journal box assembly. The basic design of the freight car journal bearing has been virtually the same for many years, and all indications are that this same bearing will remain in use for many years to come. In view of past performances, it must be conceded that the plain railroad journal bearing is basically sound for the loads and speeds normally encountered in railroad service, especially considering the unbelievable abuse to which it is subjected. The performance of railway bearings compares favorably with industrial type plain bearings, and the expectancy of a bearing failure per freight car is said to be once in fifteen years. Reassuring as this may be, there are far too many hot boxes. In the days of steam, when trains moved slowly and cars stood for long periods in terminals, the hot box was considered something inherent to the railroad industry as an inconvenience. However, with today's high speed diesels, longer trains and more rapid movement of cars, the hot box has ceased to be merely a nuisance, but has grown to be a problem of major concern to all levels of railway management.

It is realized that many hot boxes are caused by factors other than the lubricating oil or its quality. A partial list of difficulties with railway plain bearings might include:

1. Oil starvation.
2. High localized loading of bearings due to misfitted, defective or worn bearings, defective or displaced wedges, lack of lubrication in the center plate bearing, etc.
3. Bearings scored due to abrasive foreign material.
4. Poor surface finish.
5. Bearing misalignment.
6. Waste grab.

This list is certainly not all-inclusive.

[1]This article is based upon American Society of Mechanical Engineers' technical paper number 58-A-266 titled "A Review of Some Recent Advances in Lubrication of Railway Car Journal Bearings."
[2]Association of American Railroads.

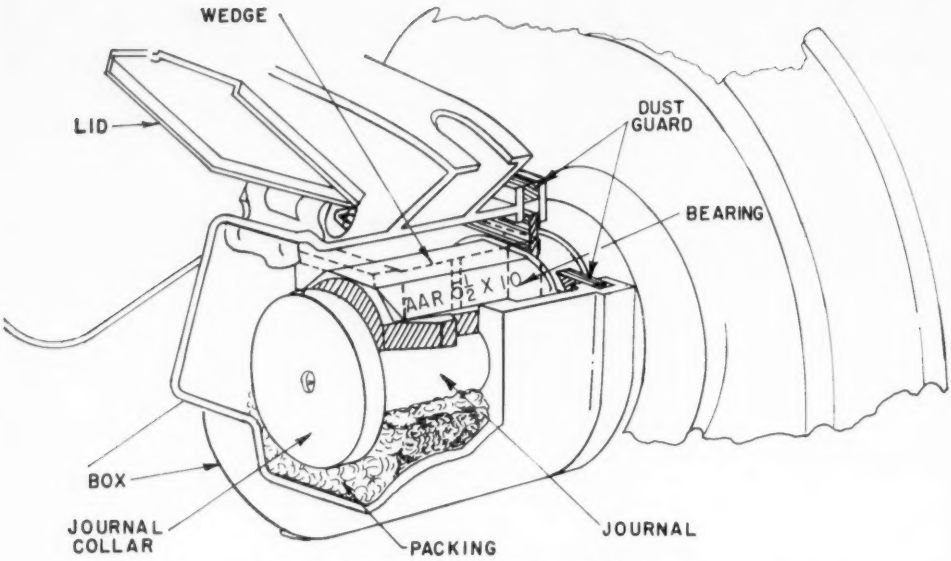
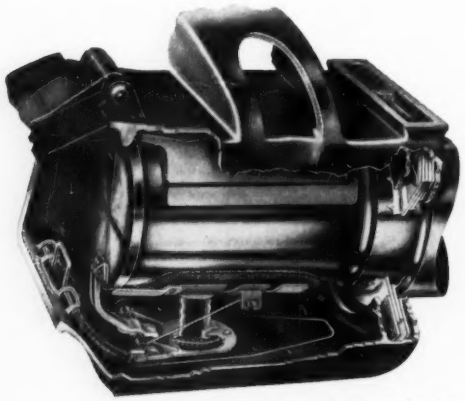


Figure 1 — Standard AAR freight car journal plain bearing.

Conversely, well seated bearings operating under normal conditions and adequately supplied with oil of the proper viscosity will perform satisfactorily; this is evidenced by the large number of bearings in actual service which operate without distress. However, it is also evident that an appreciable percentage of failures result from factors which are connected with lubricant quality. Among the characteristics of journal box oil which are considered to influence the incidence of hot boxes are load carrying capacity (the ability to lubricate effectively under adverse conditions), viscosity and, to a lesser extent, viscosity index. Indirectly, the characteristics of the wicking media which feeds oil to the journal are also of importance.

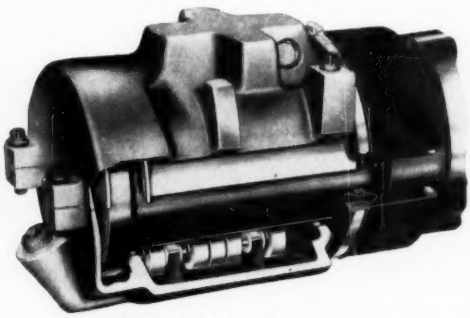
GENERAL CONSIDERATIONS

A sketch of a railway freight car journal plain bearing is shown in Figure 1. This is typical of the 14,600,000 plain bearings on which the 1,825,000 freight cars currently in service on the American Railroads move in their daily travels. The basic principles and characteristics of railway freight car bearings are the same as for plain bearings in general; however, there are some important practical differences. For example, the speed, load and temperature of a steam turbine are known in advance, and it is therefore an easy matter to determine the



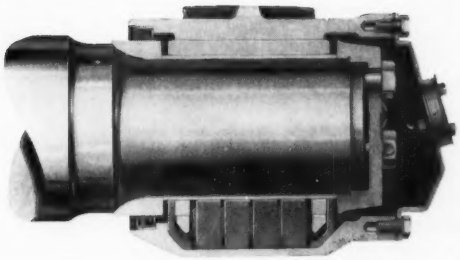
Hennessy Lubricator Co., Inc.

Figure 2 — Mechanical lubricator.



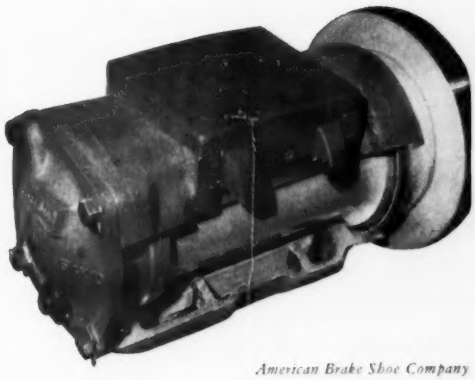
Cleveland Graphite Bronze Div., Clevite Corp.

Figure 3 — Sealed sleeve-bearing cartridge.



Allison Div., General Motors Corp.

Figure 4 — Sealed sleeve-bearing cartridge.



American Brake Shoe Company

Figure 5 — Sealed sleeve-bearing cartridge.

proper oil viscosity required to lubricate it. In a railroad bearing all of these factors are variable, some over a wide range, and the physical characteristics of the car oil used are a compromise intended to satisfy as wide a variety of conditions as possible. Current car journal oil specifications are therefore based on experience and know-how on the part of the railroad operators.

Although the design shown in Figure 1 is basic, and will probably remain unchanged because of the vast numbers of such bearings in service, a number of innovations and improvements have been introduced relatively recently. Among these are journal stops, improved dust guards, mechanical and pad lubricators and sealed cartridge bearings. A mechanical lubricator is shown in Figure 2. The pad-type oil distributor is fed by a pump actuated by the axle-end movement while the car is running. A special oil-sealing dust guard is used. The bottom of the journal box acts as the oil reservoir for this device. Pad lubricators of many various designs have appeared in recent years. As will be discussed later they offer several advantages over the historic waste packing which they are intended to replace. Their use in freight cars in interchange will be mandatory by 1960. The oil wicking characteristics of lubricator pads and the effect on bearing performance will be discussed in a following section.

Three types of sealed cartridge bearings are shown in Figures 3, 4, and 5. Although these bearings are classified as plain journal, or sleeve bearings, their design and construction are quite different from

Cleveland Graphite Bronze Div., Clevite Corp.

Figure 6 — Cartridge bearing mounted on freight car truck.

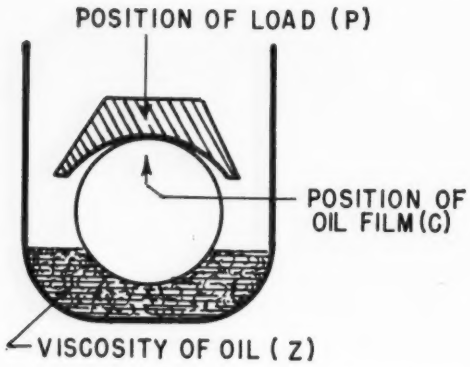


Figure 7 — Little or no oil film with car at rest.

the conventional freight car bearing. The journal and bearing are machined to close tolerances, making the assembly a precision unit. In some designs, a special bearing alloy is used. The quantity of oil in these bearings is only about one fourth that in a conventional bearing, and roller bearing or automotive type seals minimize loss of oil and ingress of dirt and water. Inasmuch as these bearings are self-contained units designed to operate for extended periods without addition of oil, a high quality, oxidation inhibited lubricant is recommended for use in these units. These bearings reduce inspection time and, as previously mentioned, eliminate the necessity for "free oiling", i.e. periodic oil additions. Service tests indicate that trouble-free operation can be expected. Figure 6 shows a cartridge bearing mounted on a freight car truck.

Grease lubrication of the standard AAR journal bearing assembly has been considered, and investigated on full scale laboratory equipment. It was concluded that grease lubrication is technically feasible, since the grease circulation was satisfactory and the friction developed with grease was comparable to oil. However, to be practical, an improved sealing arrangement would be necessary.

Freight cars equipped with roller bearings are also in service on many railroads. Although some of these cars are in special, or captive service, many others are in general interchange. Performance of roller bearings has been most satisfactory. For a more complete discussion of railway roller bearings, the reader is referred to a previous issue of this publication[3].

The formation of an oil film in a plain railway journal bearing is normally produced by the rotation of the journal in the presence of the lubricant. Stages in the establishment of an oil film are shown in the schematic cross sections of Figures 7, 8, 9 and 10. For clarity, proportions and clearances are exaggerated.

Figure 7 represents the car at rest. The position of the load is shown by "P", the oil film by "C". In this case the oil film is not the continually changing oil film which will be produced later by the rotation of the journal, but rather the oil remaining in the bearing from the previous operation. A number of circumstances could cause the oil film to be squeezed out of the load area and permit direct contact between the steel of the journal and the babbitt lining of the bearing. Some of these are: long standing; heavy loads; low oil viscosity; high localized loading of bearings due to misfitted, defective or worn bearings, or defective or misplaced wedges; scored bearings; poor surface finish; bearing misalignment. Ordinarily, enough oil remains in the bearing system to provide lubrication under intermittent metal-to-metal contact, often referred to as "boundary" lubrication. Occasionally, however, a sufficient supply of oil may not be available for adequate lubrication immediately after the car begins to move after standing.

In Figure 8 the journal has just started to turn with a speed of N. Pressure due to the motion of the car through the bearing and onto the journal has shifted the position of the oil film (if any) and the area of metal-to-metal contact to point C. Oil is being carried by the journal toward the bearing surface for the first formation of an oil film, however the process has not progressed far enough due to low journal speed to form an oil film of sufficient thickness to completely separate the metal surfaces. Under unfavorable circumstances, such as those previously described, uncontrolled generation of heat is entirely possible due to excessive sliding friction. To assist the bearing in operating under these unfavorable conditions without additional distress until a hydrodynamic oil film can be established, a

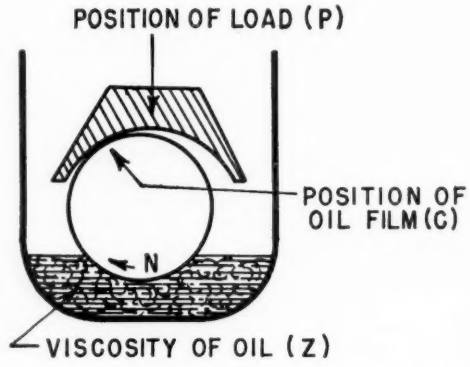


Figure 8 — Thin oil film when car is just beginning to move.

[3]Magazine Lubrication, Dec. 1954, "Progress in Railroad Bearing Lubrication."

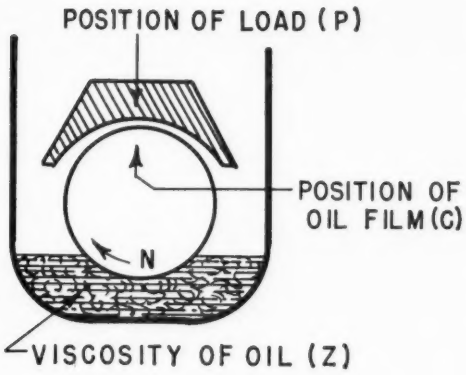


Figure 9 — Buildup of oil film with increased speed.

high load carrying capacity premium car oil is highly desirable.

As shown in Figure 9, the increasing speed of the journal, N, with the resultant formation of hydrodynamic oil pressure has established a finite oil film, which has shifted back to its original position C. While metal-to-metal contact may not have been completely eliminated as yet, operating conditions are more favorable than before the fluid oil film was established between the journal and bearing.

Figure 10 illustrates how a further increase in speed has established equilibrium under full fluid film, or hydrodynamic lubrication conditions. Hydrodynamic pressure has introduced an oil wedge between the journal and bearing, and the point of minimum oil film thickness has been shifted to point C. The bearing floats on a film of oil, and there is no metal contact. Although it has been calculated that the oil film averages between only 0.0002 and 0.0003 inches at the minimum point under normal fluid film conditions, friction in the bearing system is low, being influenced mainly by the viscosity of the oil and the contact between the journal and the waste packing or lubricator pad. Under normal fluid film conditions, hot boxes do not occur. However the rapidity at which bearing operation progresses from boundary to fluid film lubrication depends upon the controllable factors of unit loading, oil viscosity, and the difference (nominally 0.015″) between the bearing and journal radii. It is possible that a fluid film may never be established if the bearing is in poor condition or the oil viscosity is low. In extreme cases, boundary conditions may prevail over much of the range of speed encountered in freight train service.

With a reduction in speed, the above sequence is reversed. However, an important difference is that during long runs, the heat generated by shearing the oil film has probably reduced its viscosity. Thus the loss of hydrodynamic pressure which accompanies deceleration, together with a reduction in viscosity, may be sufficient to reestablish boundary lubrication conditions. As was the case when unfavorable conditions were noted under acceleration before an oil film was established, here again an oil with a high load capacity is desirable to reduce the possibility of uncontrolled heat generation.

The observations noted above in the discussion of the establishment of an oil film in a railroad car journal plain bearing agree fairly well with actual freight train operation. An appreciable percentage of hot boxes occur within a few miles after trains leave the yards or as they reduce speed approaching terminals.

The establishment and maintenance of an adequate oil film is extremely important in the successful operation of plain railway journal bearings. Under unusually severe operating conditions where the film cannot be readily established, or where it breaks down, a heavy duty premium car oil has decided advantages over straight mineral car oil.

The operating characteristics of a plain railroad journal bearing are shown in Figure 11. This is the familiar ZN/P — coefficient of friction relationship which illustrates the changes in friction with changes in load, speed and oil viscosity.

A point of minimum coefficient of friction exists at Point A which separates the boundary and fluid film regions. From this point an increase in either speed or oil viscosity or a reduction in load moves the friction value along the portion of the curve A toward B in the favorable fluid film region. Conversely, a reduction in either speed or oil viscosity, or an increase in load transfers the friction value along the A-D portion of the curve, which represents the unfavorable boundary lubrication region. A number of abnormal conditions within the bearing assembly can and do result in very high unit loading, and cause the bearing to operate in the boundary lubrication region where an adequate oil

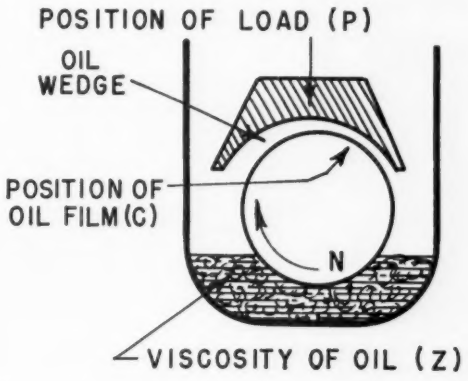


Figure 10 — Establishment of a full oil film.

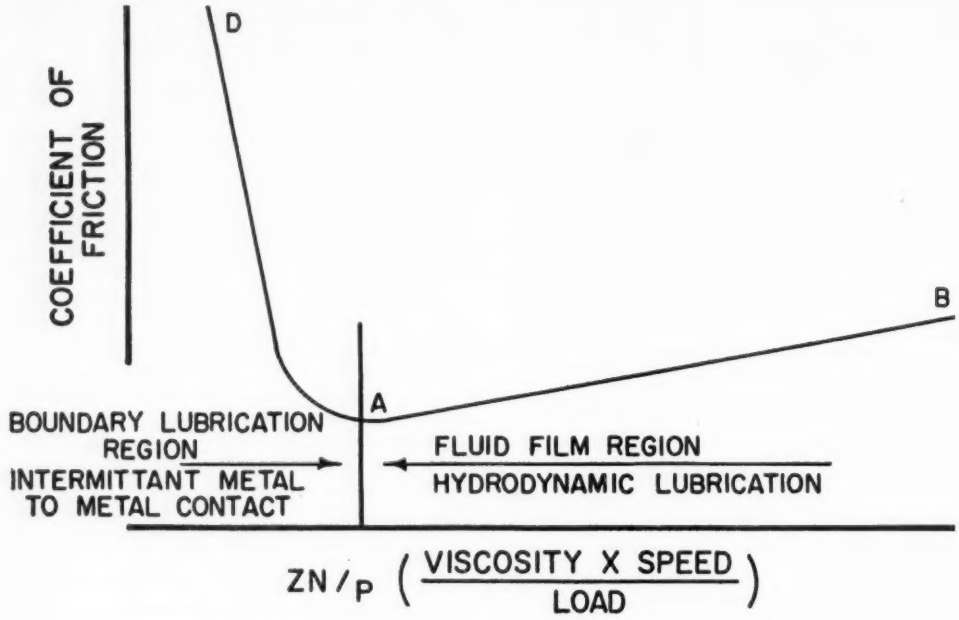


Figure 11 — Operating characteristics of a plain railroad journal bearing.

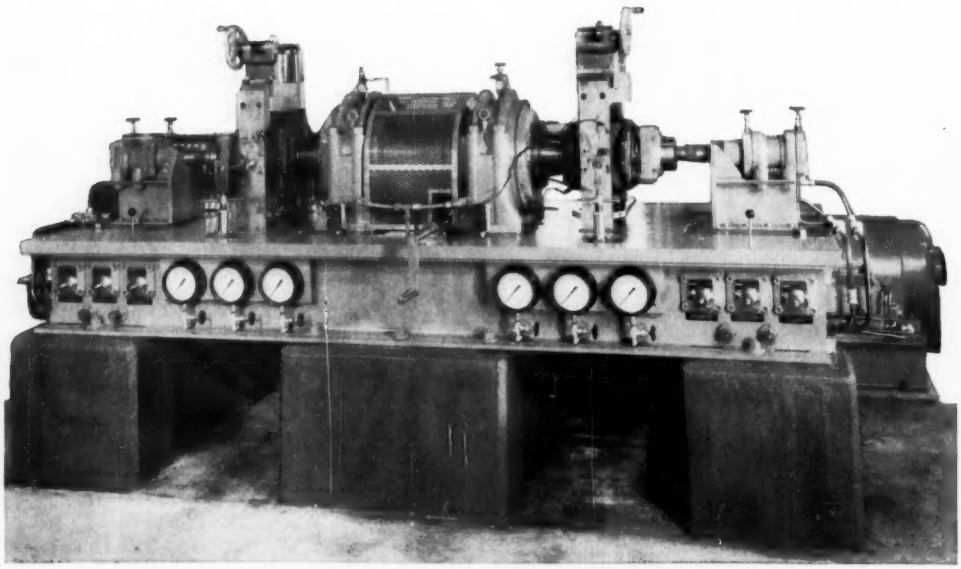


Figure 12 — Railroad journal bearing test machine.

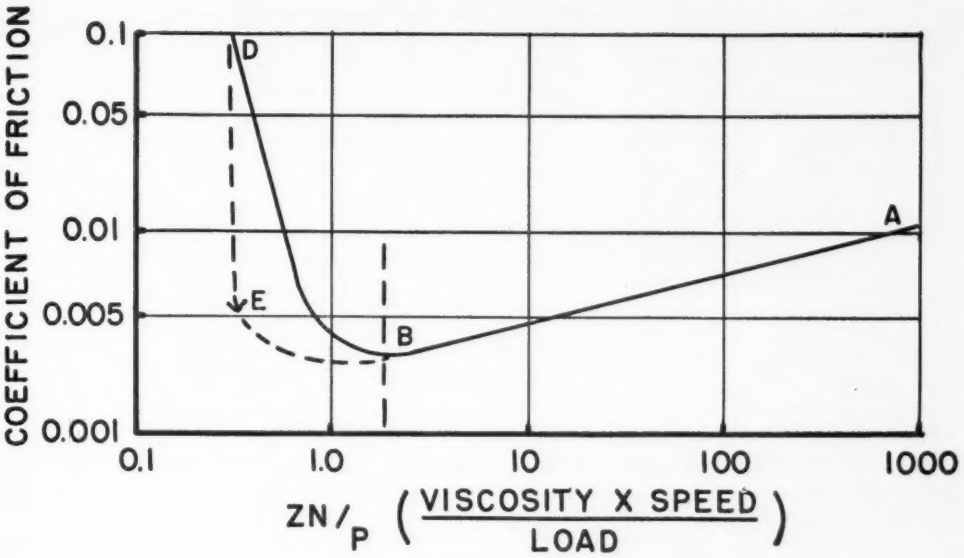


Figure 13 — Reduction of boundary lubrication friction with improved lubricants.

film is not functioning. Moreover, by virtue of the fact that when a car is stationary, the journal speed is zero, the quantity ZN/P is also zero. Therefore every freight car bearing, regardless of its own particular operating characteristics or previous history, must progress through the critical low ZN/P region on acceleration before it reaches hydrodynamic lubrication, and again must pass from hydrodynamic lubrication through boundary lubrication upon decelerating to a stop. These facts confirm the previous contention that many hot boxes occur on trains just leaving or approaching terminals.

The influence that additives have in favorably altering the ZN/P function is discussed in the next section.

Full Scale Testing

The railroad journal bearing test machine shown in Figure 12 was specifically designed and installed in a major oil company's research laboratory to study the lubrication of full scale railroad journal bearings under conditions simulating those encountered in actual railroad service. It has been used in car oil research to evaluate the performance characteristics of improved car oils and to demonstrate their effectiveness in full scale bearings.

This machine is so designed that steady vertical loads up to 38,000 pounds and steady horizontal loads up to 15,000 pounds may be applied to the bearing through a hydraulically operated loading system. In addition, vertical shock loads can be superimposed on the steady load to simulate the bearing load experienced as a result of passing over rail partings, frogs, etc. Horizontal shock loading may also be superimposed to duplicate bearing loading on curves or passing crossovers. Shock loading frequencies may be varied up to 400 cycles per minute to correspond to the simulated speed of the car. Operating speeds may be varied from the equivalent of 0.5 to 100 miles per hour train speed. Complete instrumentation is available to measure bearing temperatures, speed, load and friction. The operating parameters of this machine are shown in Table I.

During the early phases of the work with the railroad journal bearing test machine, a variety of oils were evaluated under full fluid film conditions. The small differences noted were within the repeatability of the test procedure, and it was concluded that under hydrodynamic lubrication any AAR-906-

TABLE I

Railroad Journal Bearing Test Machine

Variable	*Range*
Speed, RPM	5 to 1000 (½ to 100 MPH)
Load, Pounds/bearing	1,000 to 38,000
Oil Temperature, °F.	135 to 250
ZN/P	0.035 to 1000
Coefficient of Friction measurement range	0.0007 to 0.14

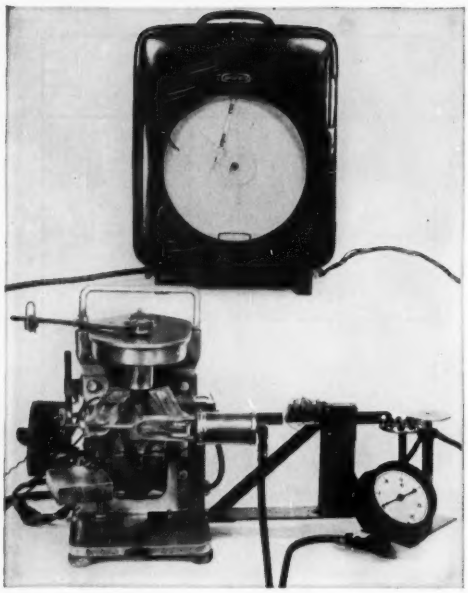


Figure 14 — Modified falex lubricant tester.

56 specification oil would perform satisfactorily. This served not only to confirm the more theoretical aspects of plain bearing lubrication, but also supported the fact that for each bearing that fails in actual railway service, there are many which operate quite satisfactorily. Results of this phase of the work are summarized along the A-B portion of the curve shown in Figure 13.

It thus became apparent that attention should be directed both toward increasing the severity of test conditions on the full scale machine and working with experimental car oil formulations which might show differences in the boundary lubrication region. By increasing the load and reducing both oil viscosity and speed, the ZN/P — coefficient of friction curve for straight mineral non additive car oil was extended to B-D, Figure 10. The high coefficient of friction value of 0.1 at a ZN/P value of about 0.5 demonstrated that even with a copious supply of lubricant (spray lubrication), critical conditions can be realized in railroad journal bearings. With the apparatus operating under these severe conditions, the straight mineral oil in the system was replaced with a premium additive type car oil. A gradual drop in friction took place, and, as operation continued, the coefficient of friction was reduced to 0.005, Point E, Figure 13. Thus it was proved that real differences, such as would be reflected in actual railway service, exist between car oils when tested under boundary lubrication conditions.

Reduced Scale Testing

Although much fundamental understanding of car journal lubrication has been obtained on the full scale Railroad Journal Bearing Test Machine, other important information has been obtained on reduced scale equipment. One such apparatus illustrated in Figure 14 is the Falex Lubricant Tester machine which has been equipped with improved loading and friction-measuring devices, and modified to use a steel pin turning between two AAR babbitt test blocks. In this machine the babbitt test blocks are pressed against the rotating steel pin by jaws through which the load is applied. The steel pin and babbitt blocks are completely immersed in the test lubricant, and the temperature of the steel-babbitt-oil system is maintained at 150°F. for the duration of the test. The friction developed is measured over a range of loads. When used to determine wear characteristics, the babbitt specimens are examined for failure after a two hour period of testing at constant load. Tests are run at various loads until the failure load is determined.

As previously indicated and illustrated in Figure 14 several important modifications have been made to the original machine which have appreciably increased its versatility and reliability. A hydraulic loading device was developed which replaces the standard ratchet wheel and turnbuckle assembly and permits smoother, completely uniform and more precise loading. The friction torque produced by the steel pin rubbing on the babbitt blocks causes a deflection in a strain beam equipped with strain patches and is recorded on an automatic circular strain recorder. The test specimens used in this test are carefully cast from AAR babbitt to insure uniform grain structure, since this has been found to be a variable which seriously affects results if not controlled. The advantages of these modifications are: (1) wear which normally occurs during a run is automatically compensated for by the hydraulic loading device; (2) the grain structure of the babbitt blocks is maintained at a uniform size; (3) friction torque is measured more accurately; (4) the repeatability of the test procedure is such that marked differences between good and poor lubricants can always be shown.

Figure 15 shows comparative anti-frictional characteristics of a straight mineral AAR specification car oil and two additive type car oils. With the non-additive straight mineral car oil, friction increases rapidly as the load is applied, and the friction curve soon goes off scale. This typical friction curve has been observed consistently with straight mineral oils in the AAR car oil viscosity range, regardless of their source. The second curve, marked "Additive Oil A", represents the anti-frictional characteristics of a conventional additive type car oil. There is a considerable

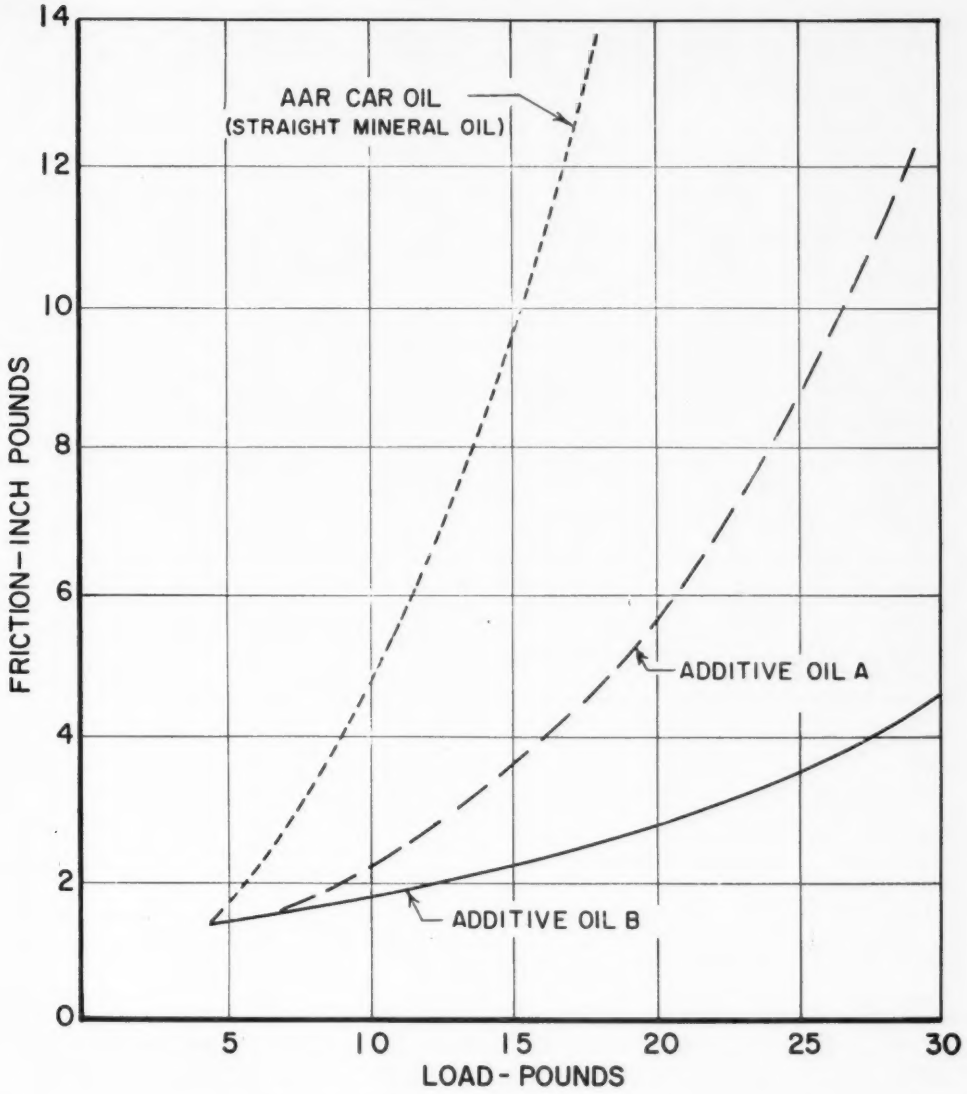


Figure 15 — Falex friction data, AAR babbitt on steel pins.

difference in the load carrying capacity of this product over its straight mineral counterpart. The third curve marked "Additive Oil B" shows the load carrying capacity of an improved premium type car oil. Even at the load limit of this test, roughly equivalent to 2,200 pounds per square inch, the friction curve has not begun its characteristic upward swing. A sixfold increase in load has only about doubled the friction developed. Since these friction curves are characteristic of steel on AAR babbitt, it follows that the same situation exists in actual railroad service, and the full scale testing has confirmed these observations. Actual railway service has also confirmed the benefit of additive oils.

Excessive friction usually means excessive wear. In order to understand how an additive type premium car oil improves wear rates under adverse conditions, further tests were conducted on the

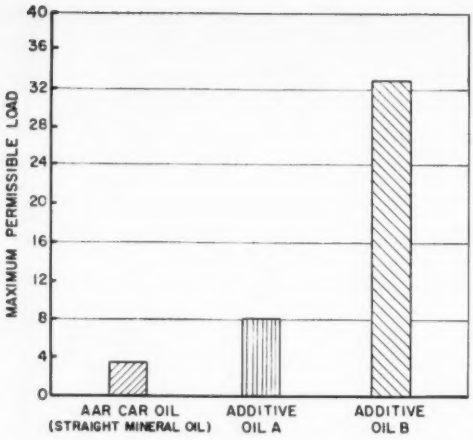


Figure 16 — Falex wear resistance data, babbitt on steel.

Falex Friction Tester. Rather than measuring friction, however, this time two hour tests were run at each of several loads to determine at what point the bearing metal fails. The results of this work are summarized in Figure 16. The babbitt fails at a relatively low load with straight mineral oil, showing that this type of lubricant offers a minimum of protection. The typical additive type car oil gives a two-fold improvement, but the improved premium type car oil provides nearly eight times more protection to AAR babbitt than straight mineral oil and four times that of the typical additive oil.

An important feature of these wear studies was the observation of the *type* of failure which occurs. In observing the results with straight mineral oils, mass shifting and destruction of the babbitt takes place, apparently due to overheating and plastic flow. An entirely different type of reaction takes place with heavy duty premium type car oil. Thin layers of babbitt are removed and then redeposited in layers — this occurring at loads far in excess of those which failed the babbitt lubricated with straight mineral oil. Figure 17 illustrates new specimens and the two types of wear patterns. It is reasonable to conclude that the wear preventive characteristics of heavy duty premim type car oil aids bearings in distress not only by preventing gross metal removal (which could result in catastrophic destruction of the bearing lining) but also by assisting in reseating with a minimum of metal disturbance.

WICKING

The formation of an oil film in a plain railway journal bearing has been shown to be dependent upon the rotation of the journal in the presence of the lubricant. In reality, the oil supply depends upon how efficiently the waste packing or lubricator pad "wicks" the oil from the oil reservoir in the journal box. Various lubricator pads[4] intended for eventual replacement of the traditional waste packing have become available in recent years, and the 1960 deadline by the AAR for their complete adoption has focused considerable interest in them. In this connection, some rather elaborate studies have been made on the wicking rates of some typical pad lubricators, as well as a typical waste packed box.

The wicking test apparatus[5], shown in Figure 18, is designed with a three-compartment box surrounding a full scale journal. The internal box dimensions are the same as a standard railroad journal box. Oil is maintained at a constant level in the center compartment from which it is wicked to the journal by means of the lubricator pad under investigation. A nylon scraper blade removes the oil from the journal and flows it into the two end compartments

[4]See March 1958 and February 1959 issues of "Railway Locomotive and Cars," for 27 different types.
[5]Patterned after an original design by The American Brake Shoe Co., Mahwah, New Jersey.

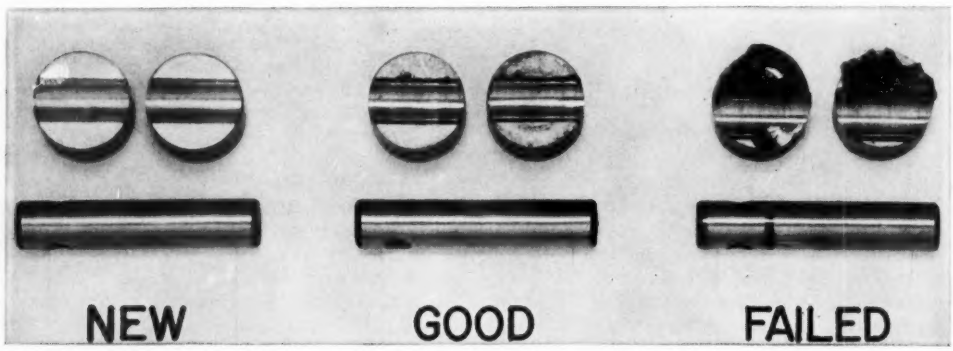


Figure 17 — Typical test specimens, Falex 2-hour wear test.

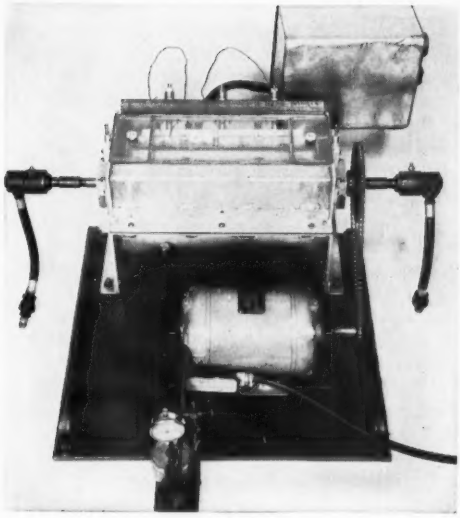


Figure 18 — Wicking test apparatus.

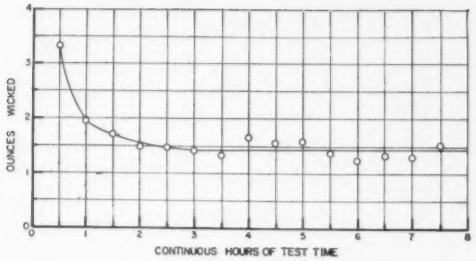


Figure 19 — Effect of time on wicking rate.

from which it is drained and weighed to determine wicking or feeding rate. The primary intent of the investigation described in this section was to study the relationship between oil viscosity and the wicking rates of several lubricators. Consequently, provisions were made in the apparatus to maintain a uniform temperature (and uniform viscosity) throughout the oil system. This was accomplished by installing the apparatus in a temperature controlled box for ambient temperature control and by circulating a coolant through the hollow journal to remove the frictional heat generated as the journal rubbed against the lubricator and the scraper. As shown below, the use of this technique made possible the direct correlation of oil viscosity and wicking rates.

Figure 19 illustrates the effect of time on wicking rate. Initially the feeding rate is high, but as the test continues, the rate drops rapidly, and soon levels out at a constant rate, indicating an equilibrium between the rate of oil removal and

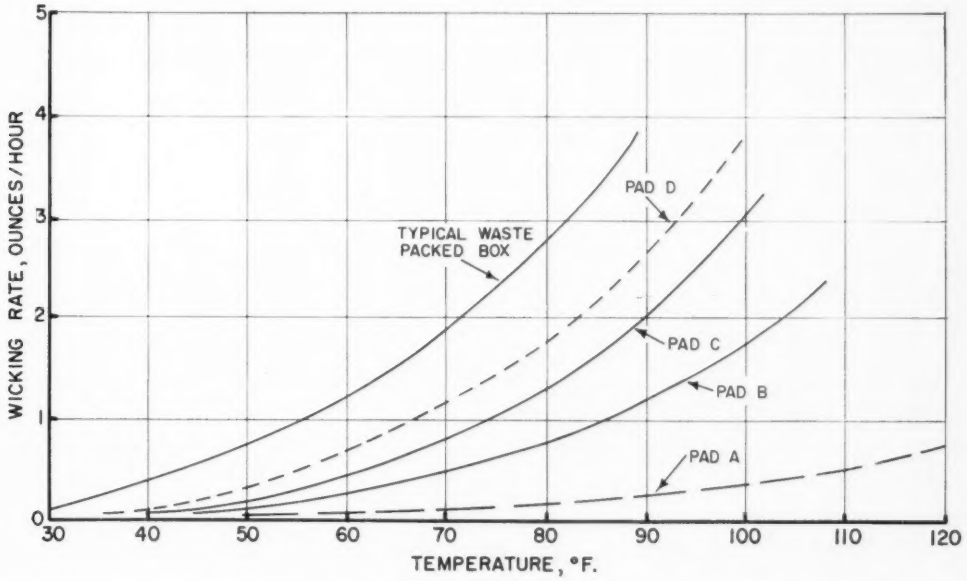


Figure 20 — Effect of temperature on the wicking rates of four commercial lubricator pads and a typical waste-packed box with AAR specification car oil.

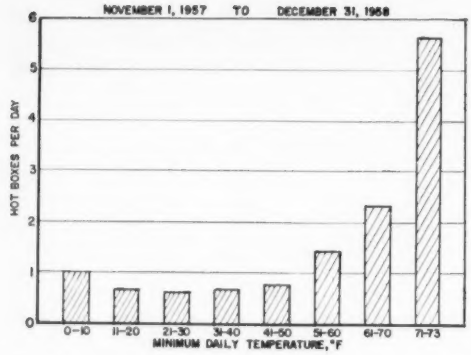


Figure 21 — Relation between hot box frequency and ambient temperature during period November 1, 1957, to December 31, 1958.

replacement by the pad. In this work, wicking rates are measured on the straight line portions of the curve.

Figure 20 shows the effect of temperature on the wicking rates of AAR Specification M-906 Car Oil in four commercial pads and also in a typical waste packed box. These data clearly indicate that there are tremendous differences among various pads, and that none wicked oil as well as the old fashioned waste. The performance of the poorly performing Pad A is particularly significant in that the wicking rate is so low as to virtually cease at 50°F. The wicking characteristics of pads at low temperatures seems to be a logical explanation of their relatively poor performance in periods of cold weather, and indicate the desirability of seasonal grades of car oil to compensate for this deficiency particularly since pads are so beneficial otherwise. Furthermore, these data demonstrate that specifications which limit viscosity at low temperatures are unrealistic, since virtually no oil is wicked in the 0°F. to 10°F. range.

It is appreciated that this test method does not simulate actual railroad service in that heat generated by mechanical friction is not permitted to accumulate in the equipment and raise the temperature of the oil. In actual service, normal friction raises and maintains the temperature of the oil above the ambient temperature. Therefore, pads in service continue to function satisfactorily at temperatures well below those shown in Figure 20. A survey of hot box incidence rate on a major railroad during a recent fourteen month period indicated performance at intermediate temperatures to be fairly normal until the ambient temperature dropped to 0°F. - 10°F. This particular railroad has a large percentage of its cars converted to pads. The results of this survey are shown in Figure 21. These data confirm railway operating experience, namely that hot boxes are most troublesome during the summer season when ambient temperatures are high. However, the data indicate in addition that a minor problem also exists at the low temperature end.

Figure 22 is a plot of wicking rates versus Saybolt viscosity. These data are not restricted to AAR

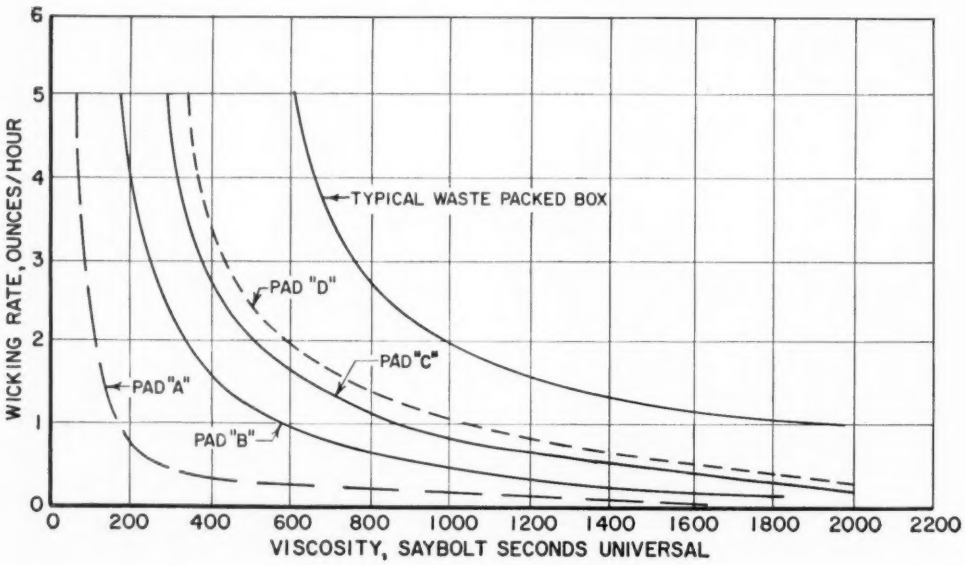


Figure 22 — Effect of oil viscosity on the wicking rates of four commercial lubricator pads and a typical waste-packed box.

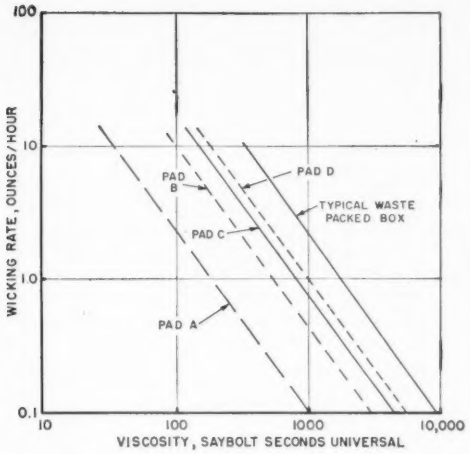


Figure 23 — Effect of oil viscosity on the wicking rates of four commercial lubricator pads and a typical waste-packed box.

specification car oil, but include a number of oils of various viscosities and viscosity indices. These same data are plotted on log-log coordinates in Figure 23. Plotted in this manner, the wicking rates of the various pads become straight line functions of viscosity. The fact that data from a variety of oils all fall on a single straight line indicates that wicking is essentially a function only of viscosity and wicking media, and the wicking rate is not influenced appreciably by the type of base oil. The straight line curves have a common equation, $W = CM^{-1.37}$, where "W" is the wicking rate in ounces per hour, "C" is the pad constant and "M" is the oil viscosity. The constant, "C", is considered to be indicative of the efficiency of the lubricator device. The constants for the various pads tested and the typical waste packed box are shown in Table II. When considered in this manner, the data suggest that the waste packed box is some forty times better than Pad A, the poorest performing pad tested.

This discussion on the wicking characteristics of lubricator pads is not intended to be an argument favoring the continued use of waste, and should not be interpreted as such. Actually, pads alleviate many of the difficulties inherent to waste, such as waste "grabs" (the cause of many a hot box), and loss of resiliency (which may cause the waste to settle away from the journal and cut off the oil supply). Moreover, pad equipped journal boxes do not require as close or frequent inspection and maintenance as waste. However, experience of major railroads shows that while pads perform far better than waste in summer, this advantage is not so pronounced in winter. It is plausible that this poorer performance of pads relative to waste during the winter season is connected with reduced wicking rates due to high oil viscosity. The winter time use of low viscosity oil to correct this tendency is discussed in the following section.

TABLE II

Pad	Constant "C"	Relative Performance
A	1,270	1
B	6,090	5
C	9,520	7.5
D	12,300	10
Waste	53,200	42

The effect of oil level in the box on wicking rates is shown in Figure 24. As would be expected, the feeding rate increases with the height of the oil in a straight line function over the range investigated. This relationship between oil height and wicking rate is particularly interesting in view of the recent AAR circular which directs that oil be added to pad equipped boxes only when no free oil is evident, and then only in sufficient quantities to raise the level to a maximum of a half inch.

VISCOSITY

In the lubrication of mechanical equipment, viscosity is usually considered to be the most important single characteristic of the lubricating oil. Ideally, the viscosity of the oil should be low enough to prevent excessive internal friction due to the oil itself, yet high enough to maintain an adequate film under any and all operating conditions. In lubricating car journal bearings, this becomes a significant problem. When operating under high ambient temperature conditions, such as those common in the South and Southwest the year around and in most of the coun-

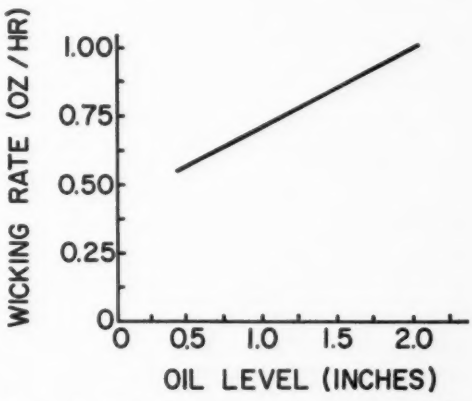


Figure 24 — Effect of oil level on wicking rate, Pad B at 70° F.

TABLE III

AAR Specification M-906-56 Journal Box Oil

Item	Method	Requirement
1) Flash	ASTM D-92	350°F. minimum
2) S.U. Vis. @ 210° F.	ASTM D88	53-58
3) Viscosity Index	ASTM D-567	100 minimum
4) Pour Point, upper	ASTM D-97	−20°F. maximum
5) Moisture	ASTM D-96	0.10% maximum
6) Pentane Insolubles	ASTM D-893	0.15% maximum
7) Acidity	AAR Method	Neutral to Methyl Orange and Phenolphthalein

try during the summer, successful operation is mainly dependent upon sufficient oil viscosity to maintain an oil film. Conversely, during severe winter conditions in the Northern part of the country, the problem becomes one of providing enough fluidity to permit circulation of the oil to the bearing. The current AAR Specification, M-906-56, is the result of much serious consideration on car oil requirements, and reflects the need and desire for a country-wide year-round car oil. The requirements of AAR Specification M-906-56 for Journal Box Oil are shown in Table III. Although the performance of freight car journal bearings is considered generally good, seasonal fluctuations in hot box incidence rates during temperature extremes tend to indicate that a single all year car oil may be inadequate, and that a more practical solution is the use of light and heavy oils for free oiling.

The use of light, free flowing oils on Northern railroads during the winter months has been standard practice for many years. In extreme cases it is necessary to free waste which has frozen to journals, by adding previously-heated free flowing oil. However, the appearance of lubricator pads has introduced another variable. Although not diminishing their other advantages, it has been demonstrated that pads do not wick oil at low temperatures as effectively as waste, and this appears to be a valid explanation for their relatively disappointing performance in winter. Free oiling with a lower viscosity oil during the winter months to compensate for increased oil viscosity at low temperatures is therefore considered the best method to restore the advantage of pads over waste during this season. Expressed in another way, reducing the viscosity of the journal box oil by free oiling with a light oil essentially lowers the temperature at which the pad will function. The experience of one major railroad, largely converted to pads, tends to confirm that light free oil is helpful during the winter season. This particular railroad uses a heavy duty type oil with a viscosity of 45 Saybolt seconds at 210°F. for this purpose.

The desirability of a high viscosity oil for summer operation can best be demonstrated by reference to the ZN/P bearing performance curve, Figure 11. Three variables—viscosity, speed and load—determine the operating characteristics of a normally performing bearing. Obviously, speeds and loads cannot be controlled in railroad service to accommodate bearing lubrication. Therefore, oil viscosity is the only remaining factor which can be varied in order to increase the ZN/P value thereby increasing the margin of operating safety. Free oiling with high viscosity oil compensates for lower oil viscosity due to higher summer ambient temperatures. There has been a recent renewed interest in higher viscosity oil, and an appreciable number of roads have actually adopted such a product for summer use. The current preference is an oil in the 70 Saybolt Second at 210°F. viscosity range, and one such heavy duty type oil, in conjunction with improved maintenance practices, has been quite successful in keeping hot boxes under control during the critical summer months. Although 70 second oils are currently in use, calculations based on blending ratios indicate that summer free oiling lubricants in the 80 to 85 Saybolt Second range would be somewhat more effective in maintaining proper journal box oil viscosity. Unfortunately, handling problems preclude the use of these higher viscosity oils, however desirable they might be.

When considered with respect to actual journal box oil viscosity requirements as they vary with seasonal changes in temperature, viscosity index as such is extremely important if an attempt is made to operate on the same grade of oil the year around. However, since ambient temperatures in this country vary at least from minus 40°F. to plus 110°F. over a single year, a much more practical solution is to compensate for seasonal temperature extremes by free oiling with light and heavy oils as the thermometer dictates. In this way the bearing is supplied with the proper grade of oil at the right time without depending upon viscosity index. By substituting seasonal grades of oil in a well planned free oiling program for a single all year oil, viscosity index loses much of its significance. For example, Figure 25 illustrates what can be accomplished with five and ten "shots"[6] of an 80 VI 84 SSU at 210°F. free oil added to 80 VI box oil at 57 SSU as com-

[6]One "shot" is assumed to be eight ounces of oil (½ pint) added to eight pints in the journal box. These data were obtained from the oil consumption records of a major railroad.

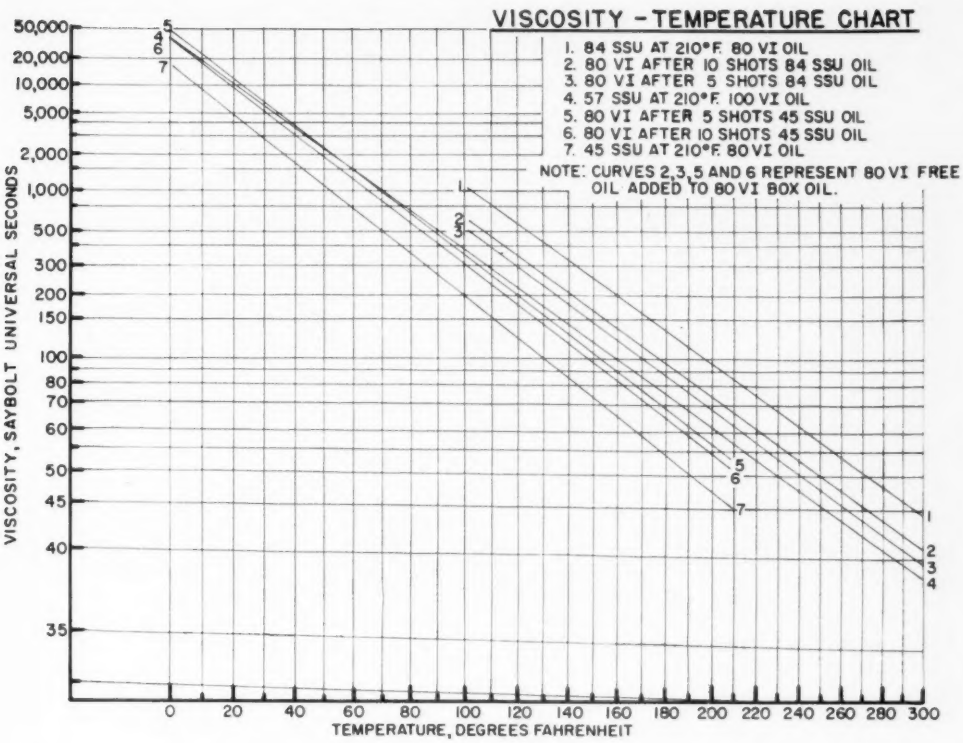


Figure 25 — Viscosity-temperature chart.

pared with 100 VI regular car oil. The gain in viscosity at higher temperatures is particularly significant. Figure 25 also illustrates the effect of five and ten "shots" of 80 VI 45 SSU at 210°F. free oil. The reduction in viscosity at lower temperatures is better than or comparable to the 100 VI regular grade car oil. These advantages of course increase with more liberal use of free oil. During the course of a year, it is possible that much of the oil will be lost from the box, and that the remaining oil will be largely representative of the free oil used. This has been confirmed by a continuous sampling program in cooperation with a major railroad. To illustrate, the curves for 80 VI 84 and 45 SSU oils are also shown in Figure 25. Here, the 80 VI free oils are far more effective in compensating for temperature changes than the single grade 100 VI oil.

Any free oiling program should, of course, receive careful consideration and planning in cooperation between the railroad's mechanical department and the oil supplier. An important feature is that free oiling with seasonal grades should be commenced far enough in advance of the seasonal temperature extremes to obtain the proper viscosity at the time desired. Other factors in determining the details of a free oiling program would be the railroad's location, type of freight traffic, and percentage of pad lubricators. For example, a southern railroad would benefit mainly from heavy oil and probably would not wish to use a winter grade of oil at all, whereas a northern railroad would be primarily interested in a light, free flowing oil for winter use. In addition to varying the oil to accommodate the season, adequate inspection and maintenance is of paramount importance in the success of car journal lubrication.

SUMMARY

Worn-in railway car journal bearings without defects operating steadily under normal conditions and with an adequate supply of oil perform satisfactorily when lubricated with straight mineral oil of the proper viscosity. Tests conducted on full scale laboratory equipment demonstrate that it is difficult to fail a bearing under these conditions simply by varying factors of load and speed. This is confirmed by the large numbers of bearings in actual service which operate without distress. Accordingly, if all bearings could be operated continuously under normal conditions with an adequate

oil supply it would be unnecessary to improve on the intrinsic ability of straight mineral oils to maintain a satisfactory lubricating film.

However, actual operating experience shows that ideal operating conditions do not always exist in railway service, since hot boxes do occur. Such factors as oil starvation, abnormal unit load, or low oil viscosity create conditions of boundary lubrication which all too frequently progress into bearing distress and failure — a hot box. In such cases of boundary lubrication, straight mineral oils have been demonstrated, both in the laboratory and in actual service, to be inadequate. It is this fact which creates the necessity to improve on the lubricating qualities of straight mineral oil and to develop oils which exceed the physical requirements of AAR Specification M-906-56. Such oils provide a factor of safety not possible with straight mineral oil by sustaining higher unit loads resulting from improper load distribution, reducing coefficients of friction and bearing temperatures, and reducing metal displacement and wear. While it is recognized that many bearing failures are due to causes which are beyond the realm of prevention by lubricant quality, it is entirely reasonable to conclude that heavy duty car oils incorporating the above improvements can and do prevent an appreciable percentage of marginal conditions from progressing to costly hot boxes.

Investigation of the characteristics of various lubricator pads indicate that wicking rates are a function of oil viscosity and wicking media only and are independent of the type of base oil. Different types of pads wick oil at greatly different rates and none of the pads tested feed oil as well as a typical waste packed box. Wicking rates at winter temperatures are negligible, and no oil feeding occurs until the bearing and journal temperatures rise and raise the temperature of the oil. Consequently, specifications restricting low temperature viscosity are unrealistic.

Seasonal grades of car oil are recommended for free oiling to compensate for increased oil viscosity and reduced wicking rates at low winter temperatures and to compensate for reduced oil viscosity and weakened fluid film lubrication during high summer temperatures. High quality, heavy duty oils in the 45 SSU at 210°F. range are recommended for winter use, while the same type of oil in the 70 SSU range is suggested for summer. When seasonal grades of car oil are used effectively, viscosity index loses much of its significance.

Good maintenance and high quality car oil is a combination which will do much to keep the hot box situation under control. The service records of several railroads which believe the plain journal bearing can be made to operate successfully support this statement.

BIBLIOGRAPHY

1. Busby, A. L. and Pigman, G. L. — "Experimental Investigation of Railroad Journal Operating Characteristics" *Lubrication Engineering,* Vol. 13, No. 10 (1957), page 546.
2. Clark, M. S. — "What Technical Improvements Have Been Accomplished to Improve Journal Box Oil" *Official Proceedings of the New York Railroad Club,* Vol. 65, No. 3 (1955), page 52.
3. Drukey, L. A. — "Lubrication of Railway Equipment Plain Bearings". Paper read before *North West Carmen's Association,* September 8, 1937.
4. Keller, W. M. and Pigman, G. L. — "Analysis of Equilibrium Operating Temperatures of Railroad Journal Bearings" *Lubrication Engineering,* Vol. 14, No. 3 (1958), page 108.
5. Meeker, R. F. and McGahey, D. C. — "A Review of Some Recent Advances in Lubrication of Railway Car Journal Plain Bearings". ASME Paper No. 58-A-266. Presented before Railroad Division, ASME Annual Meeting, December 5, 1958.
6. Plumley, H. D. — "Journal Box Lubrication" — *Lubrication Engineering,* Vol. 13, No. 11 (1957), page 592.
7. Seniff, R. W. — "Sixteen Million Journal Boxes", *Railway Purchases and Stores,* September, 1955.

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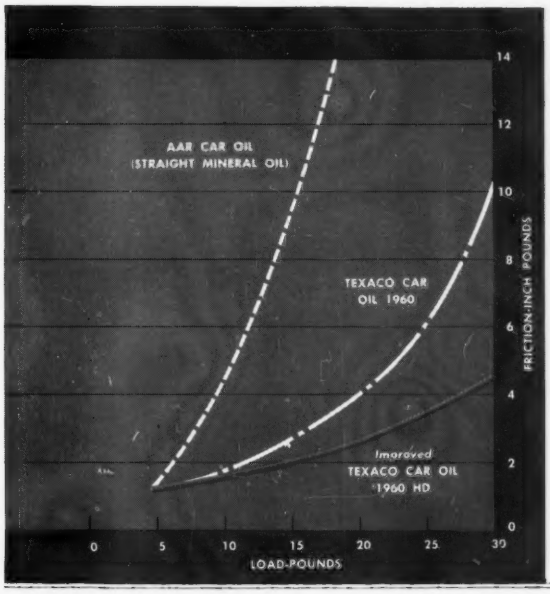

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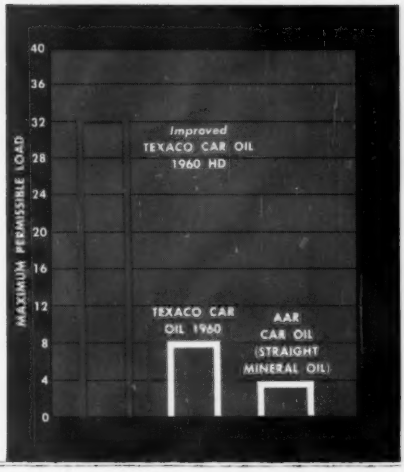

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